5 Page Phase II Plan

Topic No: N98-142

Low Cost Grating Based Laser Sensor

For Contract Period:
October 8, 1998 through April 15, 1999

Contract No: N00014-99-M-0008

Submitted to:

OFFICE OF NAVAL RESEARCH
Attn: John Thomas
800 North Quincy Street
Arlington, VA 22217-5660

Submitted by:

OPTRA, Inc.
461 Boston Street
Topsfield, MA 01983
(978) 887-6600

Principal Investigator: Craig Schwarze
Phone: (978) 887-6600 x 125
E-mail: cschwarze@optra.com

Phase I Option applied for, not yet awarded

5-PAGE PHASE II PLAN

SBIR Topic N98-142: Compact and Low Cost Airborne Laser Sensor with Recording

1. Phase II Plan

1.1 Relevance of research

This research is being done in response to the current threat that lasers pose to pilots and other flight personnel. Visible and near infrared lasers can cause significant loss of visual function due to the high susceptibility of the eye to damage by laser radiation, particularly since the eye focuses all of the collected light from a well-collimated laser beam into a small spot on the retina. This damage is even greater when binoculars or similar devices are used, since the amount of collected light is greatly increased while the spot size remains the same. The end result is that even relatively low power lasers can temporarily or permanently impair vision from ranges of tens of miles or more. The widespread commercial availability of such lasers, at a variety of wavelengths in the visible and near IR, makes this an even more serious threat.

The damage to the eye resulting from laser radiation varies from temporary visual impairment (e.g. flash blindness) to permanent vision damage and blindness, depending on the laser power level and exposure duration. Even if the visual impairment is not permanent, a momentary distraction to a pilot can have severe consequences.

The goal of this program is the development of a laser sensor that warns of the presence of a potentially harmful level of laser illumination, and records pertinent event information (laser power, wavelength, pulse duration, pulse repetition frequency, time of exposure, and an image of the scene containing the threat). Such a sensor will not only protect flight personnel from unknowing exposure, but will also generate a database of such laser exposures. This database will be a valuable tool in the development of protective devices and suitable countermeasures. A technically competent Laser Warning Sensor that meets our target cost goal of • $500 will be inexpensive enough to be installed in a large number of Naval aircraft, thus affording widespread protection to aircrews, and assuring the generation of a meaningful database.

1.2 Phase I Research

1.2.1 Phase I topic & technical objective

The Phase I topic concerned the development of a capability for identifying, recording, and analyzing potential laser threats to the vision of aircrew members during missions. The technical objective was the development of an inexpensive portable sensor that could record the following during flights of at least 4 hours duration:

- presence of a potential laser threat to vision,
- wavelength of the laser threat,
- pulse duration and repetition rate, and
- time of the laser threat.

A further technical objective was that the sensor should have a cost of no more than $500/unit when in production.

1.2.2 Phase I Results

During Phase I, a sensor was designed to meet the objectives outlined above, and a prototype was built and demonstrated to be capable of detecting potential laser threats against a fully sunlit background. The prototype further was demonstrated to be capable of recording wavelength with an accuracy of ±5 nm, as well as the location of the threat within a 40° field of view. A number of black-and-white CCD-lens combinations were tested and found to be acceptable. It appears entirely feasible that the complete sensor, including batteries and data-storage capability, will be no bigger than an audio tape cassette. Key elements of the conceptual design were (1) a small, inexpensive CCD or CMOS imaging detector, (2) a linear diffraction grating that produces a wavelength-encoded image of high-intensity light sources, and (3) an algorithm for detecting a potential threat based on real-time image data analysis. The figure below shows data images collected and analyzed during Phase I to obtain laser event information and verify the proposed design.

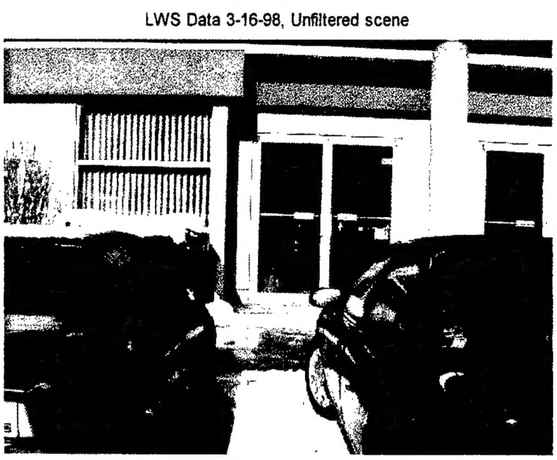

Figure 1a

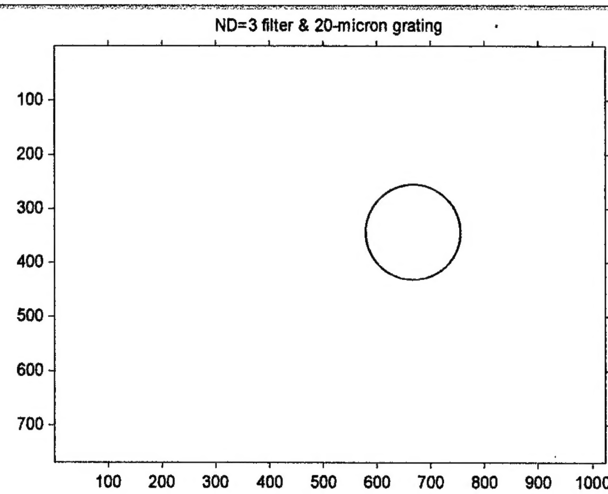

Figure 1b

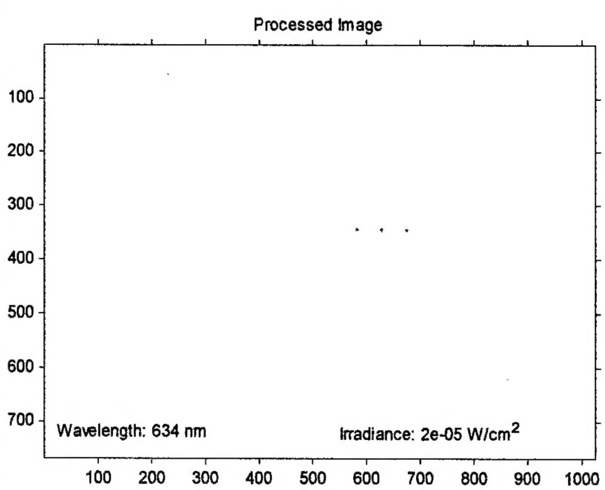

Figure 1c

Figure 1. Phase I data verifying performance of the proposed laser warning sensor. Shown in 1a) is an image of a sunlight outdoor scene with a 633-nm He:Ne laser source set just below the glare threshold and pointed out the doorway toward the camera; in 1b) is the image of the scene in (1a) obtained with the proposed laser warning sensor (the diffracted laser orders are circled); and in 1c) is the image obtained in (1b) after filtering and processing with algorithms to extract the wavelength, which is displayed in the lower half of the image along with the source irradiance.

1.3 Phase II objective

1.3.1 Overall objective

The key conceptual issues have been successfully addressed and resolved in Phase I: it is possible, using commercially available components, to build a small sensor that can detect potential laser threats, and record their wavelength, pulse duration, and repetition rate.

The key Phase II issue is to develop and package the electronics needed both for the sensor, and for a data-download module that can transfer the stored data from the sensor, analyze it, display it on a PC, and then store it permanently to a hard drive, CD, or other high-density storage medium. A further Phase II task is the design of a sensor head and data-download module that can be economically manufactured in the volume required by the Navy or other DoD elements.

1.3.2 Phase II Work Plan outline

ELECTRONIC DESIGN OF THE PORTABLE SENSOR: The sensor will continuously monitor the output from the video camera, looking for signatures from potential visual threats. All output frames will be temporarily buffered and, if a threat is detected within the frame, that frame will be stored in electronic memory together with relevant ancillary data — including temporal data from a fast non-imaging detector. We'll use commercially available components whenever we can — such as the SmartMedia miniature "digital film" cards that have been developed for consumer digital cameras.

OPTO-MECHANICAL DESIGN OF THE PORTABLE SENSOR: Once the required electronic components and batteries have been defined, OPTRA will design a compact, robust, and manufacturable package for the sensor. It will have provisions to be attached either to the pilot's helmet, or to the plastic canopy. There may be provision for an additional data-input connector so that GPS position data, etc. can be added to the ancillary data stored with each detected potential threat. There may also be provision for an audio or visual alarm indication to signal a detected potential threat.

DESIGN OF THE DATA-DOWNLOAD MODULE: After a flight during which threat data was recorded, the sensor's miniature data card can be removed and plugged into the Data-Download module — which will probably be a laptop or desktop PC. The data will be transferred for archival storage, and it can then be analyzed and displayed in detail — including a image of the scene which contained the potential threat. The exact format of the displayed data will be developed in consultation with the Phase II Technical Monitor.

SOFTWARE DEVELOPMENT: We need software both for the sensor head and for the data-download module. In the sensor head, the software will be downloaded into compact, non-volatile memory and will provide the instructions for monitoring image data and for identifying potential threats. This software will also take on miscellaneous tasks, such as ensuring that if the aircraft is continuously illuminated for an extended time, all of the memory won't be used up storing the same data over and over again.

ALGORITHM DEVELOPMENT: A major component of the software is the ability to recognize a laser source within the field-of-view and then to extract wavelength, power, and pulse information. During Phase II R&D algorithms will be developed and tested using MATLAB Digital Image Processing software to perform these operations. Upon verification of the algorithm performance, the MATLAB compiler will be used to generate the required C-code representation of the algorithms for downloading into a Digital Signal Processing (DSP) chip. This turnkey method allows the code to be easily modified for as yet undetermined future

requirements for the laser warning sensor as well as integrating other algorithms for commercial applications in machine vision and image recognition.

PROTOTYPE BUILD AND TEST: Once the designs are completed, we'll build a single engineering prototype system and test it exhaustively. We will keep the Navy continuously informed of the test results, and will look to the Navy for suggested improvements and/or modifications. After this round of testing, the prototype will be modified to remedy any shortcomings and to include any additional features, and it will be re-tested.

PRODUCTION DESIGN: When the engineering prototype work is completed, we will start the production design. This design will implement the complete functionality of the engineering prototype, but will also incorporate provisions for ease of assembly, economy of manufacture, and compact & robust packaging.

PRODUCTION PROTOTYPES: The final Phase II hardware task will be a build of two complete production prototype systems, one of which will be delivered to the Navy for extensive testing.

1.3.3 Anticipated benefits & Commercial Applications

The immediate anticipated benefit to the proposed Phase II program is the development of a recording sensor that meets the Navy's requirement to identify and document instances of laser illuminations of its aircraft that may present either a threat to aircrew vision, or designation of that aircraft as a target for enemy fire.

More generally, although the detection of potential laser threats to vision is unlikely to have a significant commercial market (other than the possible use of such sensors in commercial aircraft to counter potential terrorist threats), the tools that we develop for the Navy sensor will have a variety of applications in the commercial sector. These include the use of very low-cost imaging sensors (i.e. <$25 in quantity); the development of real-time algorithms for image analysis; techniques for filtering out unwanted image data; miniaturization of image-processing electronics; and the development of software for processing image data. Applications of these techniques will be in the fields of security and surveillance; machine vision; automated inventory control; traffic monitoring and management; patient monitoring; and other areas that we cannot yet anticipate.

1.3.4 Transition & commercialization plans

The transition of a technology from an SBIR Phase II to a viable commercial application is a complex process. In our experience, marketing plays a major role in this process, and the first step is to have a clear marketing direction in mind before even embarking on the Phase I effort. In this instance, OPTRA was particularly interested in the opportunity to develop both an improved automated image analysis capability, and to gain experience in working with small and potentially inexpensive electronic imaging devices. OPTRA's business is non-contact optical sensing, and image analysis clearly opens up a whole new range of opportunities for non-contact sensors.

In the past, OPTRA has had considerable success in converting SBIR-developed technology into viable commercial products. Most recently, OPTRA has had DARPA and Navy SBIR awards to develop a new type of optical encoder with sub-nanometer resolution and repeatability at the 5 nm level. This technology is now the basis of a $1M+ OEM business with Hewlett Packard, as well a new line of OPTRA metrology products for XY stage positioning and linear motion control. This business has allowed us to develop a manufacturing capability and to increase the size of the company by over 30% during the past 2 years.

OPTRA is currently involved in another SBIR program which involves the development of a low-cost optical sensor to replace capacitance gages in applications needing sub-micron resolution and repeatability over ranges of up to a millimeter. Even before this program is complete, we have developed a prototype commercial sensor and are beginning to work with beta-site customers. This product will nicely supplement our linear and XY encoder business, and will be brought into production using internal funding.

In summary, we feel that a successful transition strategy involves up-front marketing direction for new technology development; a licensing or OEM partnership to fund a production capability without having to raise outside capital; and a further development of the technology to tailor it to specific customer-defined applications.

1.3.5 Transitioning the technology into the Navy

We firmly believe that the proposed Phase II program will result in a sensor system that will fully meet the Navy's specifications, and that it will have enough flexibility to take on new missions through straightforward modifications to the Phase II design. If the Navy chooses to purchase such sensors from OPTRA, then we will finance the production facilities needed to meet the Navy's requirements — both in terms of quantity and delivery. The technology that is developed will also be available for licensing to a third-party manufacturer of the Navy's choosing.

1.3.6 Qualifications of Key Personnel

The detailed qualifications of OPTRA's key personnel have, of course, been provided in the Phase I proposal. The Principal Investigator, Craig Schwarze, is an seasoned systems designer who has managed a number of programs at OPTRA as well as having had highly relevant prior experience with Raytheon. OPTRA has well-trained, experienced, and imaginative optical, electronic, and software engineers — all of whom played significant roles in allowing OPTRA to complete a successful breadboard demonstration of the proposed technology during Phase I. Also, OPTRA's Chief Technical Officer, Michael Hercher — who is responsible for the optical design of the proposed sensor — was a Naval aviator.

1.3.7 Proposed facilities/equipment

OPTRA is located in Topsfield, Massachusetts and occupies a modern 10,000 square foot facility with offices, conference rooms, optics and electronic laboratories, machine shop, and manufacturing area certified to Class 10000 clean room status. All capital equipment, tooling, test and computer facilities required to perform the proposed Phase II R&D is presently at OPTRA.

1.3.8 Estimated Costs

The table below summarizes the labor and material costs for the proposed two and one-half year period of Phase II R&D, which includes the basic first year, a follow-on second year option, and a six-month bridge option.

Task	Contract	Labor	Material
Prototype Design	Basic first-year	$153,000	$20,000
Prototype Build & Test	Basic first-year	$102,000	$25,000
Production Design	Second-year option	$165,000	$10,000
Production Build & Test	Second-year option	$110,000	$15,000
Production Fixturing Design	Six-month option	$125,000	$25,000
	Total	$655,000	$95,000